

Ion Beam Manufacture of Microscale Tools and Components

Manufacturing Technologies

Sandia Manufacturing Science & Technology's Focused Ion Beam (FIB) laboratory provides an opportunity for research, development and prototyping. Currently, our scientists are developing methods for ion beam sculpting microscale tools, components and devices. This includes shaping of specialty tools such as end-mills, turning tools and indenters. Many of these have been used in ultra-precision machining DOE applications. Additionally, staff are developing the capability to ion mill geometrically-complex features and substrates. This includes the ability to sputter predetermined curved shapes of various symmetries and periodicities.

Capabilities and Expertise

- Two custom-built focused ion beam systems for precision ion milling; beam energies are 10-30 keV; target chambers have 1×10^{-7} Torr base pressure.
- Gas assisted sputtering with the aid of various chemicals; includes H₂O jet (for gas assisted sputtering of diamond).
- Focused ion beam induced chemical vapor deposition; material can be grown locally onto conductive substrates or layers in a direct-write mode; deposited material includes metals (Au, Cu) or SiO_x.
- Techniques for fabricating 3-dimensional shapes such as hemispheres, paraboloids, sine waves of various periodicities, symme-

tries and sizes.

- Techniques for shaping microtools. (See image 1 for example tools). Tools of single crystal diamond, tungsten carbide, high-speed steel are regularly made for ultra-precision machining; specialty tools, such as indenters, are possible.

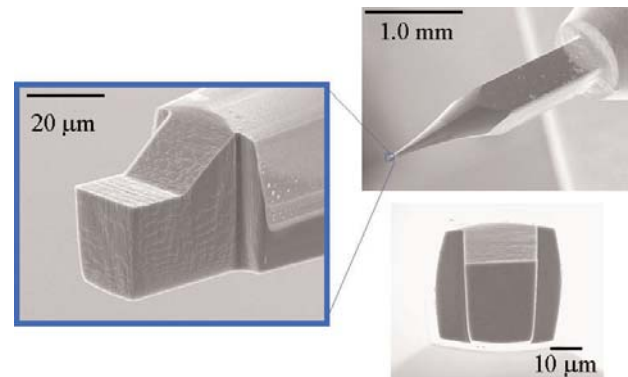


Image 1. Different perspectives of an example turning tool shaped by FIB sputtering. Tool material is single crystal diamond. Diamond is brazed into tungsten carbide mandrel.

- Ability to determine sputter yield and its dependence on incidence angle, dose for almost any material.

Resources

- Two custom-built focused ion beam systems for precision ion milling. Liquid metal gallium ion sources are used in both. System 1 has a single lens column. System 2 has a FEI, dual lens, variable aperture magnum column with CDEM. Beam sizes

can be varied from 20 nm to 1.5 μm .

- X-y stage with large travel distances. Load lock can accept up to 8" wafers.
- Rotation stage for control of ion beam incidence angle. Capable of full rotation through 360° . This also allows for sputtering of small nonplanar substrates such as tubes or fibers. (See image 2 of coil made by atomic beam lathe process).
- ADE Phase Shift white light interferometric microscope for benchtop metrology.
- Scanning electron microscopy, atomic force microscopy and other surface analysis techniques.

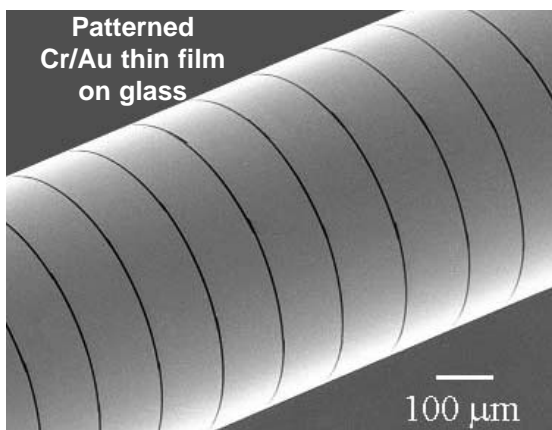


Image 2. FIB sputtered microcoil made using an atomic beam lathe process. Regions that appear dark have been bombarded to remove a Cr/Au thin film from a glass tube substrate.

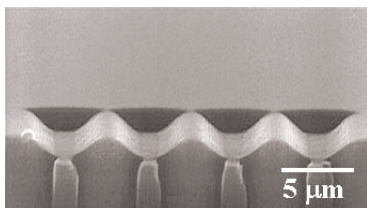


Image 3. Example sine wave FIB sputtered into initially planar Si substrate.

Accomplishments

- Developed techniques for shaping micro-cutting tools with the focused ion beam. Techniques establish a cutting edge radius of curvature equal to 40 nanometers as evidenced by transmission electron microscopy.
- Developed techniques for ion shaping predetermined, 3-dimensional features.
- Shaped target materials for LLNL/NIF high-density plasma experiments.
- Researched ion beam induced effects on yield, morphology and microstructure.
- Developing database for high energy sputter yields. Yield is determined as a function of ion beam incidence angle to 89° .

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